

ATTACHMENT

PROPOSED TEST PROCEDURES FOR HEAVY-DUTY HYBRID-ELECTRIC VEHICLES

BACKGROUND

Despite being less than five percent of the vehicle population, heavy-duty mobile source engines account for about 40 percent of oxides of nitrogen (NO_x) emissions, a smog-forming pollutant, in California. In addition, the fine particulate matter (PM) exhaust from heavy-duty diesel engines has been identified as a toxic air contaminant, which can cause cancer.

The federal Clean Air Act grants California the authority to adopt and enforce rules to control mobile source emissions within California. As such, California is the only state in the nation with the authority to establish its own unique motor vehicle control program. In doing so, California is required to adopt state requirements that are as stringent, if not more stringent, than the federal requirements.

California began regulating heavy-duty vehicles in 1969. At first, exhaust standards targeted only reactive organic gases and carbon monoxide emissions. Since then, the regulatory focus has expanded to include measures reducing NO_x and PM emissions. The state Air Resources Board (ARB or Board) adopted regulations for heavy-duty vehicles designed to reduce emissions by over 95 percent in the mid-1980s and to near-zero levels with the future 2007 standards. The ARB continues to work closely with the United States Environmental Protection Agency (U.S. EPA) to develop harmonized federal and California programs for heavy-duty vehicles. However, where it is necessary and feasible, ARB develops more stringent California programs. An example of such action is the urban bus regulation adopted by the Board in February 2000.

URBAN TRANSIT BUS REGULATION

Urban Transit Bus regulations were approved by the Board in February 2000. Beginning with the 2007 model year, urban transit buses must meet a 0.2 grams per brake horsepower-hour (g/bhp-hr) NO_x plus non-methane hydrocarbon (NO_x+NMHC) and 0.01 g/bhp-hr PM standard. Furthermore, urban transit bus agencies are required to select a path that commits the transit agency to purchase either alternative fueled or diesel fueled buses. If an urban transit bus agency selects the alternative fuel path, 85 percent of the urban transit agency's new bus purchases must be alternative fuel buses. Urban transit bus agencies selecting the diesel path are required to meet an interim 0.5 g/bhp-hr NO_x+NMHC and 0.01 g/bhp-hr PM standard by 2003. In lieu of purchasing buses that meet the interim standard, urban transit bus agencies may implement an alternative NO_x strategy that achieves greater NO_x emission reductions

than required. The alternative strategy must be approved by the ARB's Executive Officer.

As part of the requirements on urban transit bus agencies, ARB staff is required to report: (1) back to the Board regularly on the transit agency program; (2) back to the Board on implementation of emission reduction strategies as an alternative to compliance with the 2004 standards along with an analysis of the first exemption application and a recommendation; (3) on the status of the advanced aftertreatment systems; and (4) on progress and development of a hybrid-electric bus test procedure. ARB staff has presented the Board with its first update and will provide a second update this month. That update will focus on alternative NO_x strategies selected by each transit agency choosing to follow the diesel path. Some of those plans may include the use of hybrid-electric drive systems as the alternative NO_x strategy to comply with the urban transit bus requirements.

ARB staff understands that the use of hybrid-electric drive systems may significantly reduce NO_x emissions from urban transit buses, as well as the immediate need to make these systems available for sale in California. Currently, ARB staff is following heavy-duty engine based certification procedures to certify hybrid-electric drive systems for urban transit buses. Using existing certification procedures, one hybrid-electric drive system for transit buses has been certified for sale in California. The Capstone microturbine power system used in commercial hybrid-electric vehicles (HEVs) was approved by ARB based on a microturbine emissions testing cycle. Capstone microturbines fueled by diesel, compressed natural gas, or propane all received certification. In order to introduce additional heavy-duty HEVs into California's market, ARB has also approved modifications to the Carl Moyer Program that would allow funds to pay for the cost difference between a diesel urban transit bus and a hybrid-electric urban transit bus on a case-by-case basis. Currently, no hybrid-electric buses have been funded.

It is staff's understanding that current heavy-duty engine certification procedures may not evaluate full benefits provided by a hybrid-electric drive system. Hence, staff has been working with U.S. EPA, industry, academia, and the Northeast Advanced Vehicle Consortium (NAVC) to develop a chassis based test procedure that if appropriately used may be incorporated into the urban transit bus regulations as the certification procedure for hybrid-electric urban transit buses. The purpose of this workshop will be to focus on developing a proposal that appropriately incorporates a chassis based test procedure into a certification procedure that evaluates the complete emission benefits of hybrid-electric drive systems for urban transit buses. This attachment provides a brief description of hybrid-electric drive system technology, ARB's efforts in developing a procedure for evaluating full benefits of hybrid-electric drive systems, and several of the concepts for certifying hybrid-electric urban transit buses.

AVAILABLE HYBRID-ELECTRIC TECHNOLOGY FOR HEAVY-DUTY VEHICLES

Hybrid-electric propulsion systems combine two motive power sources: a Renewable Energy Storage System such as a battery pack, and an auxiliary power unit (APU) such as an internal combustion engine or turbine. An electric motor provides partial or complete power to the wheels. In addition, energy otherwise lost as heat during braking is captured through regenerative braking to charge the battery pack. In a series HEV, the APU charges the battery pack during periods of low power demand and provides power to the electric motor propelling the vehicle. In a parallel HEV, the APU provides power directly to the drive wheels in addition to the battery packs and electric motor. As the engine is not the sole power source in hybrid-electric drivetrains, a smaller engine can be used and is operated at high efficiency and low emissions. Transit buses and delivery trucks are especially good candidates for this technology, as the APU is not needed for power in many stop-and-go drive cycles, and regenerative braking during frequent stops will charge the battery system.

DEVELOPMENT OF HEAVY-DUTY HEV TEST PROCEDURES

For heavy-duty engines, the U.S. EPA and ARB ensure maximum emission reductions by adopting engine test procedures that measure emissions occurring during typical in-use driving conditions. In order to manufacture an engine for sale in California, engine manufacturers must follow the federal/ARB regulatory test procedure to certify engines to the appropriate regulatory standard or optional standard. Typically, owners of heavy-duty vehicles powered by engines certified to the optional standards are also eligible to receive either incentive funds or emission reduction credits for operating vehicles that are cleaner than required.

Future heavy-duty vehicle and urban transit bus standards will be reduced to levels nearly 50 percent lower than current standards. Hybrid-electric drive systems have the potential to allow urban transit buses to meet the already adopted urban transit bus standards and future more stringent standards. This technology can also be used in other heavy-duty vehicles to meet the upcoming October 2002 (2004) and 2007 standards. However, test procedures are needed to certify these systems in heavy-duty vehicles for sale in California. At this time, there is not an approved test procedure available to determine the appropriate emission benefits of hybrid-electric drive systems. Current heavy-duty vehicle certification is conducted using engine test procedures. As HEVs utilize both an electric motor and an internal combustion engine, engine testing alone will not reflect the contribution of the electric motor, or the emission benefits associated with it. Hence, there is need to develop a methodology for determining the actual emission benefits provided by heavy-duty hybrid-electric drive systems, specifically urban transit buses.

Development of SAE J2711

ARB staff have participated with members from industry, academia, and government in the NAVC Heavy-Duty Hybrid Certification Work Group to establish draft heavy-duty

HEV test procedures. The Society of Automotive Engineering (SAE), collaborating with the Heavy-Duty Hybrid Certification Work Group, developed a heavy-duty hybrid-electric chassis testing protocol, SAE J2711, based on the light-duty hybrid-electric chassis testing protocol J1711. This proposed recommended practice has undergone revisions and is being prepared for final approval by SAE.

Current Testing Of Heavy-Duty HEVs

ARB staff evaluated the use of the proposed SAE J2711 heavy-duty hybrid-electric procedure during testing of two hybrid-electric urban transit buses. Both the Orange County Transportation Authority New Flyer and the Torrance Transit Orion utilize series hybrid-electric drive systems. Both buses were tested on multiple runs of two driving schedules: the Central Business District schedule and the Urban Dynamometer Driving Schedule. The emissions test results from both hybrid-electric buses indicated a 50 percent reduction in total hydrocarbons and NO_x, as compared to similar sized diesel-fuel buses, as well as greater fuel economy. Based on the test results, ARB staff is proposing several concepts for public comment incorporating a modified SAE J2711 into proposals suitable for certifying hybrid-electric urban transit buses in California. These concepts are described in the section entitled "Conceptual Proposals."

Supplemental Formula

One manufacturer has provided ARB staff with a unique approach to verifying emission reductions from hybrid-electric urban transit buses. This concept will be described in detail at the upcoming workshop. The proposal includes using a mathematical formula based on engine certification data and chassis test data. To summarize, this approach accounts for the work reduction through the use of a smaller engine operating more efficiently in a hybrid drive system of an urban bus application.

An emission factor accounting for percent reduction would be developed using engine certification data and chassis data for both hybrid-electric and conventional urban transit buses. The resulting emission factor would be multiplied by the engine certification results of the engine incorporated into a hybrid-electric bus yielding the estimated emissions from the hybrid-electric urban transit bus. Use of a supplemental formula would potentially provide a method for allowing both the engine manufacturer and hybrid-electric drive system manufacturer to bear responsibility of emissions from each respective component. The question pertaining to who would assume responsibility of additional vehicle components remains unanswered.

CONCEPTUAL PROPOSALS

It is vital to California that the ARB approve test procedures that accurately measure the benefits of hybrid-electric drive systems used in urban transit buses. Hybrid-electric drive systems provide another viable option to reduce NO_x and PM emissions from heavy-duty vehicles in California. If certified, urban transit bus agencies would be able to use hybrid-electric buses to meet upcoming regulatory requirements. Test

procedures approved by ARB would provide hybrid-electric bus manufacturers with a method to measure actual benefits and allow ARB to certify this technology more easily for sale in California. ARB staff also understands the need to provide consistency throughout the heavy-duty vehicle market and develop a test procedure that would be used for all heavy-duty HEVs. However, emissions data verified and heavy-duty HEVs tested by ARB have been limited to hybrid-electric drive systems used in urban transit bus cycles. Hence, ARB staff's proposals incorporate a modified SAE J2711 as the test procedure for measuring emissions from hybrid-electric urban transit buses. Below are brief descriptions of several concepts that staff are considering for use in interim verification or certification of hybrid-electric urban transit buses sold in California. Staff is soliciting comments on these proposals. Any comments or recommendations for other methods of verifying/certifying hybrid-electric urban transit buses for sale in California may be presented at the workshop.

Verification Using A Modified SAE J2711 To Qualify For Future Incentive Programs

ARB's incentive programs are designed to provide funds to applicants using heavy-duty vehicles incorporating certified technology that reduce emissions to levels cleaner than required. For new heavy-duty vehicles, that level is considered to be "cleaner" if the engine is certified to the optional standard. Heavy-duty HEVs are currently certified using engine certification procedures, and allowed funding from existing incentive programs on a case-by-case basis, pending approval by ARB's Executive Officer. However, current engine based certification procedures may not accurately represent the drive system benefits. As a result, only one hybrid-electric urban transit bus has been certified for sale in California. This proposal would allow only hybrid-electric transit buses to be tested following a modified SAE 2711 to verify emission benefits and qualify owners of these vehicles for incentive funds. Under this proposal, hybrid-electric drive system manufacturers would be responsible for emission benefits. Vehicles qualifying for funds would be closely monitored and tested after one year to provide ARB staff with additional emissions data, and data pertaining to system durability. Staff would then use these data in developing a regulatory certification procedure to certify heavy-duty HEVs for sale in California.

Verification (Through A Sunset Date) Using A Modified SAE J2711 To Qualify For Future Incentive Programs And To Meet Alternative NOx Strategy Requirement Under The Urban Transit Bus Regulations

Heavy-duty HEVs are currently certified using approved engine certification procedures. These procedures do not account for the emission reductions resulting from the use of a smaller engine operating more efficiently in a hybrid-electric drive system. This proposal would allow hybrid-electric drive system manufacturers to sell heavy-duty HEVs testing to certification levels following a modified SAE J2711. Tested emission levels would be used for a finite period to meet the Alternative NOx Strategy requirement for urban transit bus agencies selecting the diesel path. Furthermore, heavy-duty vehicles and urban transit buses testing to levels equivalent to the optional standards and cleaner than required would also be eligible to receive funding under future incentive programs. Under this proposal, hybrid-electric drive system

manufacturers would be responsible for overall durability of components and emission benefits. Vehicles qualifying for funds or used to meet the urban transit agencies alternative NOx strategy would be closely monitored and tested after one year to provide ARB staff with additional emissions data, and data pertaining to durability of the system. Staff would then use these data in developing a regulatory certification procedure to certify heavy-duty HEVs for sale in California.

Certification Through December 2007 Following An Emission Factor Developed From Both Engine Certification And System Chassis Tests

Heavy-duty HEVs are currently certified using approved engine certification procedures. These procedures do not account for the emission reductions resulting from the use of a smaller engine operating more efficiently in a hybrid-electric drive system. This proposal would allow engine manufacturers to certify the engine to current standards following already approved engine certification procedures for heavy-duty vehicles and urban transit buses. The hybrid-electric drive system manufacturers would conduct an interim verification of actual emission benefits of the hybrid-electric drive system following the test procedures for heavy-duty HEVs provided in a modified SAE J2711. ARB, in cooperation with both engine and hybrid-electric drive system manufacturers, would determine the appropriate emission benefit factor to correlate the emission reductions between the engine certification data and chassis test data from the hybrid-electric drive system. Under this proposal, the engine manufacturer would be responsible for the emissions resulting from engine certification and durability of the engine. The hybrid-electric drive system manufacturer would be responsible for the durability of the system and any vehicle components that would affect emission benefits. Tested emission levels could be used to meet urban transit bus standards through 2007. Urban transit buses testing to levels equivalent to the optional standards would also be eligible to receive funding under future incentive programs. Buses meeting interim certification would be closely monitored and tested after one year to provide ARB staff with additional emissions data, and data pertaining to durability of the system. Staff would then use these data in developing a regulatory certification procedure to certify heavy-duty HEVs for sale in California.

Certification Using A Modified SAE J2711 Only

ARB staff could propose the use of a modified SAE-J2711 as the test procedure to certify hybrid-electric urban transit buses for sale in California. Under this proposal, the executive order would be assigned to the hybrid-electric drive system manufacturer to assume responsibility for certified emission reductions. Certified emission benefits would allow the hybrid-electric urban transit bus owner to qualify for funds provided through future incentive programs, and to meet both heavy-duty vehicle and urban transit bus requirements.

POTENTIAL IMPACTS

Depending on the testing proposal selected for approval, responsibility for testing procedures will affect urban transit agencies, engine manufacturers, and/or hybrid-electric drive system manufacturers. Estimated costs for chassis-based emissions testing range from \$70,000 to \$120,000 per hybrid-electric drive system. Laboratories equipped for heavy-duty chassis testing include Southwest Research Institute in Texas, West Virginia University Transportable Emission Testing Laboratories in West Virginia, ARB Heavy-Duty Emissions Test Laboratory in California, and Clean Air Vehicle Technology Center in California.

PROPOSED SCHEDULE

ARB staff is tentatively scheduled to present test procedures for hybrid-electric urban transit buses to the Board in Fall 2002. In order to develop a complete proposal, ARB staff will conduct two working group meetings and one workshop. Below is a tentative schedule for future meetings and the availability of a draft regulation.

1 st Working Group Meeting	April 2, 2002
Public Workshop	May 3, 2002
2 nd Working Group Meeting	May 2002
Document Available to Public	August 2002
Board Hearing	Fall 2002